E3D Modifications for Engineering Applications

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E3D is an elastic wave simulation code used for prototyping and optimizing methods for acoustic imaging and detection. Typical applications include prototyping of NIF optics inspection systems (see Fig. 1); simulating acoustic imaging in tissue; acoustical tomography methods; buried waste imaging systems; and potting void detection. Future applications include acoustic inspection systems for NIF target characterization and investigation of methods for detecting flaws in layered media.

The original E3D code was written for seismic applications and later adapted for NDE applications. New users must typically edit the code to adapt it for their specific application. Over the years several versions of the code have been created with various undocumented features. This project consolidated these versions into a single code suite, optimized it for engineering applications, and constructed a user interface. The graphical user interface enables a larger number of engineers to use the code. In addition, a users guide was created for the NDE version, with examples.

Project Goals

The project was split into three parts: building a preprocessor, modifying the kernel, and creating postprocessing tools, with the preprocessor requiring the greatest amount of effort. Part of this effort entailed constructing models for transducers commonly used in NDE. These are required for direct comparison of simulated results with experiment.

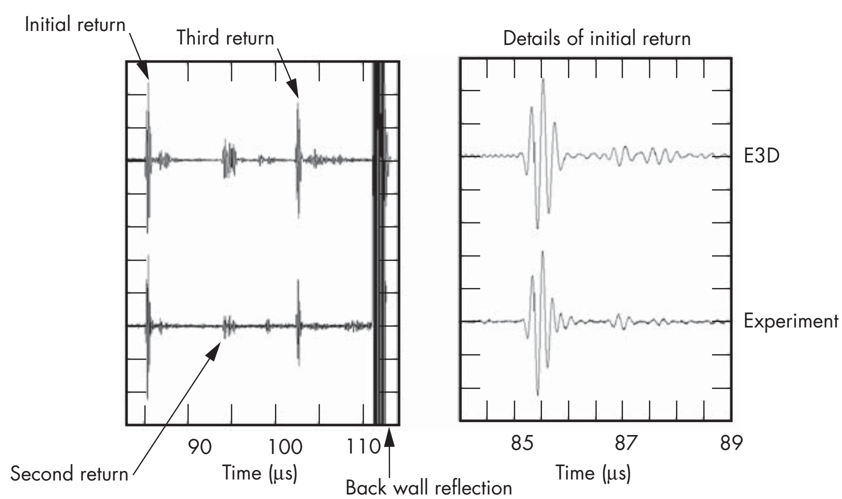

Figure 1. Acoustic reflections from surface pit in optical glass. Comparison between experiment and E3D simulation from reference article.

We also tested the existing finite-element time-domain code, created for electromagnetic problems, on an elastic wave problem. These codes represent the future of time-domain modeling because of their high accuracy and geometric flexibility. The particular problem chosen was the normal vibrational modes for an aluminum sphere. The eigenvalues for the sphere provide a sensitive indicator of the accuracy of the method. Our results showed that the finite-element code could calculate the first four eigenvalues to within 0.5%. Figure 2 shows two constant-amplitude surfaces for the fourth vibrational mode.

Relevance to LLNL Mission

E3D is an existing code at LLNL. Consolidating the different versions already in use, adding a better interface, writing documentation, and testing with experiments has been a service to the users.

FY2004 Accomplishments and Results

We constructed a graphical user interface for setting up simulations. This allows a user to specify material properties for a variety of different objects in the computational domain. User-defined objects can also be imported using a specified input file format. A menu of pre-defined focused and unfocused transducers is used to specify both transmitting and receiving elements. These use generic models to translate input voltage to the appropriate acoustic source, or samples of acoustic fields to output voltages. After the user defines the simulation, the resulting computational domain can be displayed to verify the geometry.

The different versions of the core E3D program were consolidated and bundled in a format that could be installed on any platform with Fortran and C compilers.

To determine how well our existing differential form finite-element electromagnetic codes performed on elastic wave problems, we calculated the first four eigenvalues and eigenmodes of the aluminum sphere. The results agreed to within 0.5% of the theoretical values (Fig. 2 shows the fourth eigenmode). This shows the potential for a finite-element approach to elastic wave propagation. However, the present electromagnetic code can be applied to only a very limited range of elastic propagation problems. It lacks all the differential forms required for the full range of boundary conditions in elastic wave problems. We now know the specific forms that would create a fully general elastic wave code using finite elements.

Related Reference

Martin, L. P., D. H. Chambers, and G. H. Thomas, "Experimental and Simulated Ultrasonic Characterization of Complex Damage in Fused Silica," *IEEE Trans. Ultrason., Ferroelect., Freq. Contr.,* **49** (2), pp. 255-265, 2002.

FY2005 Proposed Work

The pre- and postprocessors, new core program, and documentation are being installed on platforms in the NDE area. Additional modifications will be supported through general software maintenance or programmatic funding.

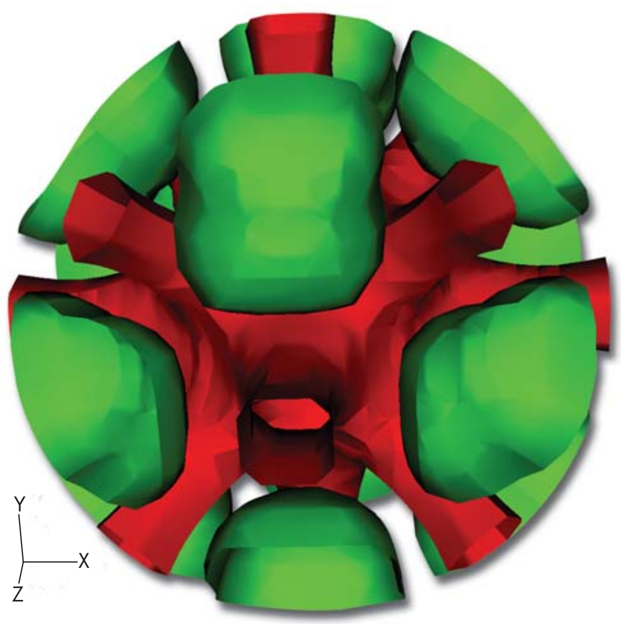

Figure 2. Constant amplitude surfaces for the fourth vibrational mode for an aluminum sphere. Calculation was performed by a high-order finite-element code originally for electromagnetic waves.